Table 2

Comparison and Summary of Selected One-Dimensional Stream Water-Quality Models

Hydraulics Computation Schemes								
Model	Hydraulic Regime	Stream System Discretization	Discretization Limits	Coordinate Scheme	Hydrodynamic Solution	Required Hydraulic Data	Calibration Criteria	Travel Times
Streeter-Phelps (USGS) Model	One-dimensional steady-state streams*	1)Main stem and branches 2)Reaches defined by inflows or stream changes 3)Computational elements Element length requirements do not increase discretization error.* Input data is by reach.*	1)50 reaches 2)950 elements 3)Elements 0.05-5 miles 4)50 total tributaries, waste inflows, and withdrawals	River miles (RM) from river mouth or arbitrary point downstream of the study segment*	None: direct specification of reach-averaged velocity, depth, and area*	Average velocity, depth, area, and top width*	None*	Directly specified* or calculated from reach velocity and length*
QUAL II Model, SEMCOG Version	One-dimensional steady-state streams* with dynamic predictions from specification of diurnal meteorological data*	1)Main stem and multiple-branched tributaries 2)Reaches 3)Elements of equal length Reach length is governed by element length.* Input data is by reach.*	1)500 elements 2)20 elements/reach 3)15 junctions with tributaries 4)90 inflow and withdrawals 5)75 reaches	River miles or kilometers from river mouth or arbitrary point downstream of the study segment*	Options 1)$u = aQ^b$ $d = \alpha Q^\beta$* 2)Trapezoidal cross section defined; velocity and depth from trial-and-error solution of Manning's equation*	1)a, b, α, β, by reach* 2)Reach-averaged values of: a)bottom width b)side slopes c)channel slope d)Manning's n *	Reach-averaged velocity and depth*	Calculated from reach volumes and discharge*
WQRRS Model	One-dimensional steady-state*, gradually varied, or fully dynamic stream and reservoir networks	1)Networks with flow reversals 2)Reaches 3)Nodes and elements Input data is by study segment. Three element lengths/reach can be specified.*	1)100 elements* 2)105 nodes* 3)10 reaches* 4)10 inflows, withdrawals, and nonpoint source zones.* 5)41 cross-sections defined*	Same as QUAL II, some distances specified in meters and RK (feet and RM) and a common vertical datum, usually mean sea level*	Steady Options 1)Stage-discharge relationship 2)Backwater solution* Unsteady Options 1)St. Venant equation 2)Kinematic wave 3)Muskingum routing 4)Modified Puls routing	1)Channel slope 2)Manning's n 3)x-section location 4)x-section coordinates or elev. vs. area, hyd. radius, top width 5)Channel encroachment and conveyance 6)Boundary conditions, downstream depth, elev. vs. discharge, and headwater discharge 7)Initial conditions, discharge, and water surface elevation	Water surface elevations, velocity and depth at discrete grid points*	Calculated from reach volumes and discharge*
MIT Transient Water Quality Network Model	One-dimensional steady-state or dynamic flow in stream and estuary networks	1)Networks with flow reversals 2)Nodes at junctions headwaters and controls 3)Reaches between nodes 4)Mesh spacing Mesh spacing may vary for hydraulics and water quality. Rate coefficients specified by zones.	Depends on Courant stability criteria. User modifies program dimensions to fit the network modeled. Limits specified by user.	Feet from upstream end of reach and a common vertical datum, usually mean sea level	Solution of one-dimensional continuity and momentum equations by implicit finite element method (Galerkin tech.)	1)Slope 2)Manning's n 3)x-section location 4)x-section elev. vs. top width, area, wetted perimeter, and conveyance areas or pipe radius 5)Conveyance limits 6)Boundary conditions, downstream depth, elev. vs. discharge, headwater discharge 7)Initial conditions, discharge, and water surface elevation	Same as the WQRRS Model	Calculated from reach volumes and discharge

Water-Quality Computation Schemes									
			Temperature Simulation						
Model	Longitudinal Dispersion	Water Quality Solution	Method	Data	Calibration	Reaction Rate Temp. Adj. θ	DO Balance	Biochemical Oxygen Demand	Reaeration
Streeter-Phelps (USGS) Model	Neglected	Analytical	None: directly specified*	Reach-averaged temperature	None	BOD decay 1.047 Benthic DO demand 1.065 Reaeration, fecal and total coliform die-off 1.0241 Benthic demand and net photosynthetic production 1.0 All others 1.09	1)Reaeration* 2)BOD decay* 3)Nitrification* 4)Photosynthesis* (mean daily) 5)Respiration 6)Benthic demand*	1)1st-order decay 2)Settling or scour of BOD described by the difference in two 1st-order reactions*	1st-order reaction* 1)Directly specified by reach* 2)Bennett-Rathbun eq.* 3)Langbien-Durum eq. 4)Velz method 5)O'Conner-Dobbins eq. 6)Tsivoglou-Wallace eq. 7)Padden-Gloyna eq. 8)Bansal eq. 9)Parkhurst-Pomeroy eq.
QUAL II Model, SEMCOG Version	Calculated for straight, infinitely wide channels; too low for natural channels	Implicit finite difference approximation with tri-diagonal matrix solution	1)Directly specified** 2)Heat balance with surface flux only*	Temperature by reach* % cloudiness, dry-bulb and wet-bulb temperature, pressure, and wind speed*	None Wind-speed function* and dust-attenuation factor	Reaeration 1.0159 BOD settling 1.0 All others 1.047	Same as the Streeter-Phelps model	1)1st-order decay* 2)1st-order settling*	1)Directly specified by reach* 2)Churchill and others eq. 3)O'Conner-Dobbins eq. 4)Owens and others eq. 5)Langbien-Durum eq. 6)Thackston-Krenkel eq. 7)Tsivoglou-Wallace eq. 8)$K_2 = aQ^b$
WQRRS Model	Included with no details of calculation	Finite difference approximation with matrix solution	1)Directly specified** 2)Heat balance with surface and bottom flux* 3)Equilibrium temperature method**	Temperature by specified zones % cloudiness, dry-bulb and wet-bulb temperature, pressure, wind speed Equilibrium temperature coefficient, solar short-wave radiation, wind speed, vapor pressure	None Wind-speed function, atmospheric-turbidity factor, and bed heat capacity coefficient Equilibrium temperature coefficient	Default Coliform die-off 1.04 Reaeration 1.022 BOD, NH_3, NO_2, detritus, sediment decay, nongrowth bio-activity and ecological and sediment constituents — see documentation	1)Reaeration* 2)BOD decay* 3)Nitrification* 4)Photosynthesis* 5)Respiration 6)Detritus decay* 7)Sediment decay	1)1st-order decay of dissolved BOD* 2)Particulate BOD modeled with organic detritus* 5-day BOD is specified as input data	Same as QUAL II except (8), and direct input is by element
MIT Transient Water Quality Network Model	Calculated as a function of an estuary dispersion parameter, longitudinal salinity gradient, Taylor's dispersion coefficient, and a factor for bends and irregularities	Finite element solution	1)Directly specified 2)Heat balance with surface flux only	Temperature by reach Air temperature, relative humidity, wind speed, net solar radiation, net atmospheric radiation, pressure	None None †	Default BOD decay 1.047 Reaeration 1.016 Coliform die-off 1.045 Nitrogen decay 1.065	1)Reaeration 2)BOD decay 3)Nitrification	1)1st-order decay	$K_2 = C\frac{V^{0.6}H_B}{H^{1.4}A}$ C specified by reach

Water-Quality Computation Schemes (continued)						
Model	Benthic Demand	Aquatic Plants and Animals	Nitrification Cycle	Orthophosphate-Phosphorus	Coliform Bacteria	Other Options or Constituents
Streeter-Phelps (USGS) Model	Zero order or constant benthic uptake	Direct specification of chlorophyll a by reach and net daily photosynthetic DO production	1)Nitrogenous BOD 1st-order decay* 2)Nitrogenous BOD zero-order decay (not mentioned in current documentation)** 3)Nitrification* a)Organic-N b)NH_3-N c)NO_2-N d)NO_3-N	1)1st-order uptake by chlorophyll a 2)1st-order sedimentation or scour	1st-order die-off 1)Fecal* 2)Total*	1)Anoxic conditions a)length of zone b)BOD remaining 2)3 arbitrary conservative substances*
QUAL II Model, SEMCOG Version	Zero order or constant benthic uptake	Phytoplankton as measured by chlorophyll a	Components* 1)NH_3-N 2)NO_2-N 3)NO_3-N 4)Algae	1)Algae uptake 2)Algae release 3)Zero-order benthos source/sink	1st-order die-off 1)Total*	1)Flow augmentation 2)Treatment plant % BOD reduction specified 3)1 nonconservative substance 4)3 conservative substances*
WQRRS Model	1)1st-order organic sediment decay 2)Benthic plant respiration and photosynthesis	1)Benthic algae 2)Phytoplankton 3)Zooplankton 4)Aquatic insects 5)Fish 6)Benthic animals	1st-order decay with complex ecological interactions (see documentation for complete details) 1)NH_3-N* 2)NO_2-N* 3)NO_3-N** 4)Biota 5)Organic detritus*	1)Biota release or uptake 2)1st-order detritus and organic sediment decay and release	1st-order die-off 1)Total	1)Suspended sediment 2)Unit toxicity 3)PH-total alkalinity 4)CO_2 cycle 5)Organic and inorganic sediment 6)Food chain
MIT Transient Water Quality Network Model	Not considered	1)Phytoplankton 2)Zooplankton	Components 1)NH_3-N 2)NO_2-N 3)NO_3-N 4)Phytoplankton-N 5)Zooplankton-N 6)Particulate organic-N 7)Dissolved organic-N	Not considered	1st-order die-off 1)Fecal	1)Salinity coupled to hydrodynamics

Program Utility						
	Input Data		Output Data			
Model	Problems	Advantages	Problems	Advantages	Model Advantages	Model Disadvantages
Streeter-Phelps (USGS) Model	1)Poor organization 2)Program does not check input data	1)Reaches added or deleted with ease 2)Documentation gives good explanation or input data	1)Lengthy output— no option to shorten	1)Results line printer plotted 2)Internal computations summarized	1)Easy to calibrate with line printer plots 2)Direct input of travel time 3)Anaerobic zones estimated 4)Analytical solution, no numerical instabilities 5)Discretion errors are limited 6)Nitrogenous BOD can be modeled 7)Nitrification option is flexible	1)No flow routing 2)No temperature simulation 3)No algae or biomass simulation 4)BOD scour is treated as a 1st-order process
QUAL II Model, SEMCOG Version	1)Some algae must always be entered even when algae option is not used**	1)Excellent coding sheets-efficient and well organized 2)Reaches added or deleted with ease 3)Excellent explanation of input data by documentation 4)Good internal checks on data	1)Results are not plotted and are not stored for post-processing plot program (a version does exist to do this)	1)Concise, well-organized output 2)Output lists input data and summarizes internal computations 3)Option available to suppress parts of output	1)Model is well organized into subroutines that can be easily modified 2)Model will calculate required flow augmentation given DO standards 3)Percent treatment for STP BOD can be specified 4)Phytoplankton can be modeled 5)Temperature can be modeled	1)Organic nitrogen is not modeled explicitly 2)Calibration can be tedious 3)Discretization errors can be significant 4)DO saturation is not corrected for barometric pressure 5)Escape of NH_3 to atmosphere is not addressed
WQRRS Model	1)No coding sheets 2)Documentation is vague in some areas	1)A common input format is used 2)A wide range of coefficients are given default values	1)Difficult to calibrate stream hydraulics module with travel time 2)Nitrite is not listed in output	1)Results can be written on files to transfer to other segments or other programs 2)The amount of printed data can be controlled	1)A wide range of parameters can be modeled 2)Options are available for sensitivity analysis or exploring management alternatives 3)One-dimensional lakes can be included in a system 4)Suspended solids are modeled	1)Some criteria for the choice of coefficients are vague or nonexistent in a few cases 2)Dynamic options are complex and make the program difficult to apply 3)Components in a cycle cannot be isolated 4)Data requirements are vague in a few cases
MIT Transient Water Quality Network Model	1)Input data is not fully explained	1)A common input format is used 2)A wide range of coefficients are given default values 3)Internal checks on input data is adequate	†	1)Plotting files are created for post-processing	1)Inflows and coefficients are easy to specify 2)Dispersion and several other model parameters can be controlled with specified data †	1)Reaeration coefficient specification is severely limited 2)Program does not check for numerical convergence 3)Some criteria for the choice of model coefficients are vague †

* Option or capability verified in this evaluation.

** Problem corrected in the most recent update. The Streeter-Phelps model was updated April 1981, NCASI updated the QUAL II model, SEMCOG version October 1980, and the HEC updated the WQRRS model June 1981.

† The MIT program was not fully evaluated.